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**A REPORT TO CONGRESS
ON THE
STRATEGIC DEFENSE INITIATIVE
DEPLOYMENT SCHEDULE**

**As Requested By
Section 215, FY 87 Authorization Bill**

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EXECUTIVE SUMMARY

The attached report was prepared in accordance with Section 215, *Report on the Strategic Defense Initiative Deployment Schedule*, included in the FY 87 Authorization Bill. The requirements of that section are listed in the preface to the report. The basic requirement is to show how SDI-developed technology and systems can enhance other defensive missions and systems. This report presents the results of the SDIO assessment.

The report provides a description of defensive missions and functions and related SDI technologies that could provide a basis for their improvement. These missions and functions have been divided into five major categories with each presenting a short summary of the factors relating to the particular element of defense, a review of related SDI technologies, and an assessment of possible future technology developments. The sections will provide estimated costs for developing applicable SDI technology but not costs for a specific conventional system since these are undefined at this point.

The principal focus of the Strategic Defense Initiative program is to develop technology needed to support an informed decision on whether to proceed to full scale engineering development and subsequent deployment of a ballistic missile strategic defense system that would eventually result in a defense-dominated strategy. The SDI technologies will provide the basis for developing defensive systems for deployment in layers (in space, in the air, on the ground or at sea), to increase the probability of successful missile intercept. Even initial deployments of a layered defense could introduce sufficient uncertainty in the mind of a potential aggressor about the outcome of a ballistic missile strike and thus deter an attack. Chapter One of this report discusses the systems which we are pursuing as near-term SDI options and important military capabilities they could produce.

Another obvious near term benefit of our SDI efforts may be the capability to defend U.S. and allied forces from the threat of shorter range ballistic missiles. From its inception SDI has had a mandate to examine defenses against all ballistic missiles,

including those shorter range systems--nuclear, chemical, and conventional--which threaten our allies. The Soviet arsenal of tactical missiles is becoming more capable and threatening, especially to high value theater assets such as command and control nodes, air defense sites, redeployment centers, and nuclear retaliatory systems. The development of systems capable of providing significant early warning, attack assessment, battle management, and system kill against medium and short range ballistic missiles, is critical. The SDI FLAGE (Flexible, Lightweight, Agile Experiment) technology, for example, clearly could contribute to this mission; however, other activities such as the design of defense architectures for theater defense are also very important. Chapter Two addresses technology programs being pursued by SDI, which may have application in this area. It also discusses the military pay-off to be obtained from such capabilities.

Direct application and spinoff from the SDIO program can provide significant enhancement of conventional missions and systems in both the near and far term. In the near term, valuable spinoff from the SDI program has already occurred in the process of meeting the demanding requirements of the SDI mission. These developments can be rapidly applied to improve existing conventional weapons. As the SDI program moves forward, additional technologies will mature to provide evolutionary changes to conventional systems. These advances will result in new systems which can profoundly change the nature of modern conventional defense. Further, SDI-developed tools and techniques for achieving cost and reliability improvements in the manufacture of advanced technology systems can also improve the producibility, cost and utility of conventional systems. The third chapter of this report deals with these issues in greater detail. Specifically, it provides a review of the requirement for tactical and strategic air defense and the role of SDIO technologies in their potential improvements; the national need for access to space; a review of the generic improvements to conventional warfighting systems using SDIO technologies; and the impact of SDI technology and systems on fleet operations.

The fourth chapter provides an assessment of the need for defense of U.S. and allied space-based assets, and how SDI technologies can make that defense possible. National communications, intelligence collection, weather sensors, and navigation systems are increasingly central to the operation of any modern military establishment. Yet they are, to varying degrees, vulnerable to attack and destruction. SDI technology can provide the

capability for defending these national assets against direct attack and for surviving in the rigorous environment of space through the use of hardening techniques, improved reliability, and new power generation systems.

The last chapter addresses SDI's capabilities to provide near-term, advanced, space-based surveillance and tracking sensors to serve a variety of national security purposes. The development of sensor systems needed to determine the initiation of a missile attack, then process and communicate the information to the battle managers and weapon systems, will also be able to provide this capability for the benefit of other missions such as fleet operations, night operations, aircraft control, and target sensing.

The data presented in the above sections are not intended as a final, all-inclusive listing of the many potential applications of SDIO-developed technology to other missions. To the contrary, this report can provide little more than a preliminary perspective of a dynamic and extremely promising technology development effort. The full contribution of SDI technologies to national and allied security and civil technology, we can only estimate today. It seems clear, however, that the SDI program will be a very valuable resource for technology. The potential application of SDIO technology is extensive across defense elements, since each defense program (land forces, naval forces, tactical air forces, and nuclear forces) can make use of these technologies to improve current systems and enhance the capability of future systems. The opportunities to improve support systems in the national infrastructure are also broad. For example, communications satellite reliability and operation, weather monitoring and analysis, manufacturing techniques and materials use, and medical applications of lasers or other systems are just a few examples of benefits that the nation would accrue from this broad range of technical analysis. It is clear that the Strategic Defense Initiative, a broad and complex technical program, will provide a basis for the technical improvement of our nation's defense and that of our allies from the improvement of conventional systems to the development of complex space defenses.

The impact of SDI technology on conventional defenses is recognized in the Conventional Defense Initiative (CDI) program established by Congress late last year. The CDI plan under development by OSD will include numerous projects that apply spinoff

technology from SDIO weapon, sensor and battle management/C³ projects. The DoD Report to Congress on the CDI plan will elaborate further on this subject.

PREFACE

The Defense Authorization Act, 1987, contained the following:

SEC. 215. REPORT ON STRATEGIC DEFENSE INITIATIVE DEPLOYMENT SCHEDULE (U)

- (a) **REPORT REQUIREMENT**—The Secretary of Defense shall submit to Congress a report detailing what Strategic Defense Initiative technologies can be developed or deployed within the next 5 to 10 years to defend against significant military threats and help accomplish critical military missions. The missions to be considered include—
 - (1) defending United States Armed Forces abroad and United States allies against tactical ballistic missiles, particularly new and highly accurate Soviet shorter range ballistic missiles armed with conventional, chemical, or nuclear warheads;
 - (2) defending against a limited but militarily effective Soviet attack aimed at disrupting the National Command Authority and other valuable military assets;
 - (3) providing sufficient warning and tracking information to defend or effectively evade possible Soviet attacks against military satellites including those in high orbits; and
 - (4) providing early warning and attack assessment information and the necessary survivable command, control, and communication to defend against possible Soviet conventional or strategic attacks.
- (b) **ADDITIONAL MATERIAL TO BE INCLUDED**—The report shall—
 - (1) identify any other significant near-term military mission that the application of Strategic Defense Initiative technologies might help accomplish;

- (2) list what specific program elements of the Strategic Defense Initiative are pertinent to these applications;
- (3) estimate initial operating capability dates for the systems needed to accomplish these missions;
- (4) estimate the level of funding necessary for each program to reach these operating capability dates; and
- (5) estimate the survivability and cost effectiveness at the margin of these systems against current and projected Soviet threats.

(c) **DEADLINE FOR REPORT**--The report under subsection (a) shall be submitted not later than March 15, 1987.

This report satisfies that requirement.

GLOSSARY OF TERMS

BM/C ³	Battle Management, Command, Control, Communications
BSTS	Boost Phase Surveillance and Track System
DEW	Directed Energy Weapons
EMG	Electro-magnetic Gun
EML	Electro-magnetic Launch
ERIS	Exoatmospheric Reentry Vehicle Intercept System
EWAA	Early Warning Attack Assessment
FLAGE	Flexible Lightweight Agile Guided Experiment
GBL	Ground-based Laser
GBLW	Ground-based Laser Weapon
GBR	Ground-based Radar
HEDI	High Endoatmospheric Intercept Missile
HLLV	Heavy Lift Launch Vehicle
HVG	Hypervelocity Gun
ICBM	Intercontinental Ballistic Missile
ID	Interactive Discrimination
KEW	Kinetic Energy Weapon
KKV	Kinetic Kill Vehicle
LOC	Line of Communication
LWIR	Long-wavelength Infrared Radar
NATO	North Atlantic Treaty Organization
NCA	National Command Authority
NPB	Neutral Particle Beam
OTH	Over the Horizon
RV	Reentry Vehicle
SA/BM	Systems Analysis and Battle Management
SATKA	Surveillance, Acquisition, Tracking, and Kill Assessment
SBES	Space-based Engagement System
SBL	Space-based Laser

SBLW	Space-based Laser Weapon
SBNPBW	Space-based Neutral Particle Beam Weapon
SBR	Space-based Radar
SDI	Strategic Defense Initiative
SDIO	Strategic Defense Initiative Organization
SLBM	Submarine-launched Ballistic Missile
SLKT	Survivability, Lethality and Key Technologies
SRBM	Short-range Ballistic Missiles
SNF	Short-range Nuclear Force
SRINF	Shorter-range Intermediate Nuclear Force
SSTS	Space-based Surveillance and Tracking System
TBM	Tactical Ballistic Missile
TMD	Theater Missile Defense
TWT	Traveling Wave Tube

INTRODUCTION

The development of defensive systems is dependent upon a variety of requirements and the availability of technology, but the key to an effective defensive system is its ability to deter aggression through the development of uncertainty on the outcome of the battle. That is, any potential adversary should know that his contemplated attack will be met by systems that will endure and respond in kind. The design requirements for modern defensive systems can be summarized in three concepts listed below. The development of SDI technology in support of its primary mission and in support of the improvement of other defensive systems will ensure that these goals are achieved.

The first requirement is military effectiveness. A defense against ballistic missiles must be able to destroy a sufficient portion of an aggressor's attacking force to deny him confidence that he can achieve his objectives. In doing so, the defense should have the potential to deny that aggressor the ability to destroy a militarily significant portion of the target base he wishes to attack.

The second requirement is survivability. Defenses must maintain a sufficient degree of effectiveness to fulfill their mission, even in the face of determined attacks on the defenses and, perhaps, loss of some individual components. Such a capability will maintain stability by discouraging such attacks. Survivability means that the defensive system must not be an appealing target for defense suppression attacks. The offense must be forced to pay a penalty if it attempts to negate the defense. This penalty should be sufficiently high in cost and/or uncertainty in achieving the required outcome that such an attack would not be contemplated seriously. Additionally, the defense system must not have an "Achilles heel." In the context of the SDI, survivability would be provided not only by specific technical "fixes" such as employing maneuver, sensor blinding, and protective shielding materials, but also by using such strategy and tactical measures as proliferation, deception, and self-defense. System survivability does not mean that each and every element of the system need to survive under all set of circumstances; rather, the defensive force as a whole must be able to achieve its mission, despite any degradation in the capability of some of its components.

The third requirement is that options generated by research be evaluated to the degree that the defensive systems discourage an adversary's attempt to overwhelm them with additional offensive capability. Technology and tactics must be available that would allow the system to evolve over an extended period to counter any plausible responsive threats. Such a robust defense should have the effect of deterring a strong offensive response and enhancing stability. In short, the Department of Defense seeks defensive options—as with other military systems—that are able to maintain their defense capabilities more easily than countermeasures could be taken to try to defeat them. This criterion is couched in terms of cost-effectiveness at the margin; however, it is much more than an economic concept.

CHAPTER ONE

EVOLUTIONARY STRATEGIC MISSILE DEFENSES

SUMMARY

At present, the United States has no defense against strategic ballistic missile systems viewed by the Soviet Union as the critical element in pursuit of its military strategy. These missiles offer a unique combination of responsiveness, swiftness, accuracy, reliability, survivability and penetrability. Such characteristics are viewed by the Soviets as critical to their ability to effect surprise, to preempt, and to employ overwhelming force at the decisive time and place. In the event of a nuclear conflict, Soviet strategy calls for the early use of ballistic missiles to cripple the opponent's ability to respond, thereby setting the stage for subsequent combined arms operations to achieve victory.

Current Soviet force posture is well designed to meet its strategic objectives. The Soviets have deployed 308 SS-18 ICBMs with over three thousand hard-target capable warheads. In addition, there are over 1000 SS-11, SS-13, SS-17, SS-19 and SS-25 ICBMs with approximately 3000 RVs. The Soviet SLBM force has increased substantially over the past decade, and now consists of some 1000 SS-N-5, 6, 8, 17, 18, 20 and 23 SLBMs with over 3000 RVs. In combination, Soviet strategic nuclear forces provide Moscow with a large prompt counterforce capability, significant operational forces to conduct strikes against soft high value military targets, and a strategic reserve for intra-war deterrence or follow-on strikes.

The goal of Strategic Defense Initiative technologies is to contribute to a defense-dominated environment that will devalue the utility of the ballistic missile. Creation of a defense architecture that would create uncertainty in the minds of Soviet planners could contribute to this goal. As the defensive capability evolved it could eventually bring the Soviets to the point where they recognized that the ballistic missile had become fundamentally incapable of achieving its military mission in support of their potential objectives.

Given an early national decision to proceed with full scale engineering development, an effective strategic defense system could be deployed in sufficient quantity and depth to provide an initial layered defense. Within the ten year period set by the terms of reference for this study, such a system would be based on near-term technologies, it would also be designed to provide for growth, both by making allowance for further technological improvements and by the addition of later supporting layers or systems. Thus, a near-term system would be but a first phase of an eventual total defensive system. As currently conceived it would consist of multiple layers to increase the probability of preventing a successful missile strike, and could be constructed as follows: a boost phase layer combining the Boost Phase Surveillance and Tracking System (BSTS) and Space-Based Kinetic Kill Vehicle (SBKKV); a midcourse layer using sensors to detect the attacking elements after they have separated from the missile and provide data for the Exoatmospheric Reentry Vehicle Interceptor System (ERIS); a terminal layer could augment earlier layers with airborne optical sensors, ground-based radars and the High Endoatmospheric Interceptors (HEDI); the entire layered defense would be managed and directed by a decentralized BM/C³ system.

The technical progress that has been made on the SDI research program over the past three years has advanced at an unexpectedly fast pace and is still accelerating. We remain convinced that the basic goal of the SDI Program is achievable. It is most likely that future decisions on deployments could have to be made on the basis of defensive options, each which would provide increments of protection from ballistic missile attack.

This evolutionary approach to strategic defense is known as the concept of phased, or incremental, deployment. Recognizing the fact that no strategic defense system could be deployed all at once, this concept of phased deployment addresses the question of how to deploy strategic defenses in the event a deployment decision is made in the future. It does not constitute a decision to deploy. Such a decision can not be made now. We continue to believe that the defense resulting from the various increments must be expected to meet our basic criteria; thus, the development and deployment of the initial phase of an evolutionary system should provide a base upon which the larger, integrated system can continue to be built and should perform a militarily useful function that contributes an increase in our

security commensurate with the commitment of resources involved. This would also increase arms control negotiating leverage for balanced reductions in offensive weapons.

The goals of defense deployments are: (1) deny the Soviets confidence in the military effectiveness and political utility of a ballistic missile attack; (2) secure significant military capability for the U.S. and its allies to deter aggression and support their mutual strategy in the event deterrence should fail; (3) secure a defense-dominated strategic environment in which the U.S. and its allies can deny to any aggressor the military utility of ballistic missile attack.

It has become clear that these goals can be reached through the phased deployment of defenses, and that incremental deployment of defenses is the only likely means of deployment. Each phase of deployment would be sized and be given sufficient capability to achieve specific military and policy objectives and to lay the groundwork for the deployment of subsequent phases. Of equal importance, the technologies employed in, and objectives served by, the initial phases of a deployment would be fully compatible with the technologies and objectives of the ultimate strategic defense system. In fact, such early phases would facilitate the achievement of the ultimate system.

In addition, the first phases could serve an intermediate military purpose by denying the predictability of Soviet attack outcome and by imposing on the Soviets significant costs to restore their attack confidence. These first phases could severely restrict Soviet attack timing by denying them cross-targeting flexibility, imposing launch window constraints, and confounding weapon-to-target assignments, particularly of their hard-target kill capable weapons. Such results could substantially enhance deterrence of Soviet aggression.

TECHNOLOGIES FOR EVOLUTIONARY DEPLOYMENT

Technologies available for a first layer of defense in the boost phase are:

- **Space-Based Boost Phase Surveillance and Tracking System (BSTS):** An orbiting launch warning satellite in high earth orbit that would

use various sensors to perform launch detection, booster identification, and booster track prediction functions. This type of system could perform surveillance and warning functions. Information from the BSTS satellite would be passed on to other SDI systems, such as the Space Surveillance and Tracking System (SSTS), Probe, Airborne Optical System (AOS), or Space-Based Kinetic Kill Vehicle (SBKKV).

- **Space-Based Kinetic Kill Vehicle (SBKKV):** This is a space-based system which would use sensors hand over information to orbiting platforms containing kinetic energy weapons. The kinetic energy weapons would use sensors to home on boosters, post-boost vehicles, or anti-satellite systems.

The midcourse layer of defense could initially be supported by the following technologies:

- **Ground-Based Late Midcourse Sensing Platforms:** Missile-borne surveillance technologies consist of on-board infrared sensors to perform discrimination and tracking functions. These "Probes", as they are called, would be used in conjunction with other elements, such as the Exoatmospheric Reentry Vehicle Interceptor System (ERIS), Airborne Optical System (AOS), and Ground-Based Radar (GBR).
- **Ground-Based Exoatmospheric Reentry Vehicle Interceptor System (ERIS):** The ERIS concept is a multi-stage kinetic kill system used to destroy incoming warheads. An on-board seeker would be used to home on the targets, based on target information given to it from other SDI sensor elements. Advanced versions would have improved capabilities.

The technologies first available for a terminal layer capability are:

- **Ground-Based High Endoatmospheric Interceptor Missile (HEDI):** This interceptor could be used for terminal defense and to engage RVs remaining from the midcourse phase of the defense. The interceptor would

accept handover data from other systems. It would use an on-board seeker to home in on the terminal-phase targets and could be used to destroy RVs from several kinds of ballistic missiles.

- **Ground-Based Radar (GBR):** This radar is a fixed discrimination and tracking system used for the terminal phase portion of the defense. An improved version of the system, incorporating software and processor upgrades to enhance its discrimination ability in order to accommodate increased threat sophistication, would follow.

Coordinated performance in each phase, together with the integration of a multi-tiered defense, is the responsibility of the Battle Management and Command, Control, Communications elements of the system. An initial capability to manage the defensive battle and command, control and communicate with high confidence during all phases of the defensive engagement involves decentralization. Specific requirements would include boost phase sensor broadcast of track information with distributed command and control on the engagement platform. This capability will grow incrementally to the point that full functionality for ground-based elements and the initial capability to manage boost phase space-borne sensors and weapons will be demonstrated, then further evolved to establish full battle management functions. Validation of system and battle management architectures will be accomplished within the environment provided from the SDI National Test Bed (NTB) program, which will achieve an early operational capability in 1988. Capabilities to be developed concurrently with battle management prototypes are those associated with a strategic defense command center which will provide techniques for human control of a strategic defense system.

A successful SDI architecture must be premised on the understanding that it would accommodate present and future U.S. strategic needs and be responsive to Soviet countermeasures. The Soviet threat is considered to exhibit an evolving capability that can be characterized by non-responsive and modified systems over the near term, moving toward more directly responsive countermeasures in the longer term. A U.S. defensive architecture must allow development of cost-effective defensive capability over the long term, even in the face of an aggressive strategic countermeasures program.

The task is to meet these requirements with an appropriate level of technology by deploying an evolutionary and time-phased architecture. This architecture would be comprised of ground, air and space-based systems within a framework that maximized the leverage of the US defense posture over existing threat and plausible near-term countermeasures. Development and deployment of a time-phased defensive system would enable the US to counter an evolving Soviet strategic threat with systems that would erode Soviet confidence in their strategic offensive forces while enabling US strategic planners indirectly to cause Soviet weapons acquisition programs to be channeled away from strategic offensive programs and toward strategic defensive programs.

FUTURE PLANS

The Strategic Defense Initiative Organization (SDIO) investment strategy which pertains to these program elements is characterized by three objectives: (1) bringing the most mature technologies to a level where, if the decision were made to proceed, the tasks of realizing the individual system concepts would primarily be one of engineering; (2) pursuing development of emerging technologies having the potential for major improvements in defense effectiveness; and (3) ensuring investments are made in innovative ideas which, although they present higher technical risk, hold the promise of great success and could yield significant payoffs in achieving a thoroughly reliable defense. This program is based on an overall systems approach and complementary systems design in lieu of an alternative and possibly suboptimized approach in which individual technologies, systems and missions are instead given isolated focus.

Follow-on technologies are essential to enhance survivability, cost effectiveness and defensive effectiveness, as well as to provide responses to possible Soviet countermeasures. In the field of sensors examples of advanced technologies now being explored include: a space-based surveillance and tracking platform, which enables more accurate tracking and discrimination; a space-based radar; and the airborne optical sensor, which could augment target tracking capability in the late mid-course. Follow-on weapon candidates include space-based and ground-based directed energy devices, which are very

valuable as interactive discrimination devices as well as weapons, and which could significantly enhance the effectiveness of the boost- and mid-course phases of the defense; and ground-based hypervelocity guns, which could be used for highly cost effective terminal defense.

CHAPTER TWO

THEATER MISSILE DEFENSE PROGRAM

SUMMARY

The Soviet concept of operations for a general war in Europe is to conduct a surprise attack, winning rapidly by overrunning and securing key areas throughout Western Europe. The Soviets are restructuring their theater forces to be better able to achieve this end by increasing the mobility and firepower of their conventional weapons while retaining nuclear systems as an option. By the mid 1990s, the Soviets will have a large force of accurate, short range ballistic missiles (SRBM) capable of attacking NATO theater assets. All SRBM systems could employ nuclear, chemical, and high-explosive warheads, and probably a submunition option. This improved accuracy coupled with range and reaction time improvements provide the means the Soviets need to accomplish operational concepts associated with a comprehensive air operations plan using tactical missile strikes to enhance corridor breakouts. We currently have no defense in place against this threat.

On 28 January 1987 the Deputy Secretary of Defense designated the Army as the lead service to develop and coordinate an Anti-tactical Missile (ATM) program that includes passive countermeasures, active defenses and counterforce options. This program is being developed with allied requirements in mind and includes, in so far as possible, cooperative allied efforts. Allied cooperative efforts are essential to the fielding of a viable response to the tactical missile threat. The ultimate goal is to develop theater missile defense capabilities that deny the Soviet planner the tactical advantage offered by more accurate, conventionally armed missiles.

The SDI technology development program for FY 87 includes \$71 million in support of the active missile defense technology related to theater missile defense, with approximately \$280 million programmed through FY 1989. Results of this program, plus

spinoffs from all SDI technology research (sensors, EMG, kinetic kill, lethality, and BM/C³) will be integrated into ATM programs as appropriate.

PROGRAM STATUS

Technology being developed in direct support of or related to theater missile defense programs can be divided into two major categories, architectural/system analyses and interim capability improvements. The results of technology development will be provided to the Army for their use in the design of theater defense systems. The status of these efforts is provided below.

Architecture Studies: These analyses will provide the basis for design and evaluation of system architectures needed to resolve the tactical missile threat in the theater. The analyses will include evaluations of the threat and the capabilities of current systems to counter that threat. They will also include recommendations on the improvement of current theater defense architectures through system improvements or alternative system development. This multinational analysis of theater defense requirements will provide a balanced appraisal of the need for theater defense systems given the identified threat and current force structure, and will present a variety of technical approaches to improving the tactical missile defense potential in the theater.

Extended Air Defense Test Bed: The Extended Air Defense Test Bed will provide a test bed for the simulation and analysis of alternative theater architectures to determine the validity of proposed solutions and the effect of change of one component on the entire system. This system will be a node to the SDI National Test Bed, but on a smaller scale, to be able to evaluate theater components (actual and simulated) and associated battle management, communications and control points, all in real time. The Test Bed, then, will be a valuable research tool that will provide theater architecture designers the information they need to properly assess proposed architectures and the merits of proposed improvements.

Survivability Analysis: Theater Missile Defense systems must survive the battlefield environment if they are to be credible and effective. SDI-sponsored survivability analyses will identify survivability issues that must be addressed in the design of such systems and meet operational goals. These analyses will also support the improvement of other systems such as communications centers, data processing centers, command and control nodes, or other technical/combat systems as more information is gathered on weapons effects, systems protection techniques, and degraded operation requirements.

Invite, Show and Test (IST): The Invite, Show, Test (IST) program will provide a forum for U.S. and Allied system(s), subsystem(s) and component(s) to be tested and evaluated for possible integration into theater missile defense systems. Articles to be selected will include kill mechanisms, sensors, BM/C³ systems, and other components. This program is unique in that it solicits technology from a world wide base. Firms from the U.S., UK, Canada, Italy, Germany, France, and Israel have expressed interest in IST. Contract awards for IST are anticipated for August 1987.

Combined Allied Defense Effort (CADE): The Combined Allied Defense Effort (CADE) is the program designed to manage the Invite, Show, and Test program and integrate other system tests results to support more informed decisions on the follow-on development of theater defense systems. The benefits of this program will be realized as the data from competing experiments are reduced and analyzed and recommendations are developed on the selection of proposed systems or subsystems. Major SDI and/or service-supported systems that the CADE manager may consider and evaluate include, but are not limited to: Raytheon PATRIOT ATM improvements, LTV FLAGE and ERINT "hit-to-kill" missiles, the French SA-90 (ASTER), and the Israeli ARROW.

Flexible Lightweight Agile Guided Experiment (FLAGE): The nonnuclear kill of conventional, chemical or nuclear warheads is the theater defense goal, and is expected to be accomplished by achieving a "hit-to-kill" capability. The FLAGE and follow-on Extended Range Interceptor Technology (ERINT) programs will demonstrate new guidance and control techniques needed to accomplish the nonnuclear kill of Tactical Ballistic Missiles. On 27 June 1986, a FLAGE missile achieved a direct hit intercept of an air launched target, demonstrating effective end game maneuver and control. The 1987 test

program, or FLAGE follow-on, will use LANCE missiles as targets. The FY 87 effort completes FLAGE and is programmed at \$10 million. The ERINT program will extend the FLAGE concepts to operate at different altitudes and ranges. The ERINT program will use existing fire control systems to manage the engagement. The ERINT program is funded at \$17 million in FY 87.

Raytheon PATRIOT ATM Follow-on: The proposal to improve PATRIOT beyond current ATM capabilities is currently unfunded but an evaluation of these improvements may become a part of IST, if funds become available.

French SA-90: The French have been developing a family of air defense weapons that will provide tactical missile defense as well. This system may be a candidate for the CADE program, but is currently unfunded.

Israeli ARROW: The ARROW system is not funded at this time. The technology to be demonstrated in the ARROW program could have application in both tactical missile defense and air defense.

OTHER SDI SUPPORTING TECHNOLOGY

SDI has made significant progress in developing efficient electromagnetic ("railgun") and electrothermal guns for accelerating guided and unguided projectiles. This technology could markedly enhance conventional defense capability against Soviet tactical and cruise missiles.

The current state of SDI optical (infrared, ultraviolet and visible spectrum) and radio frequency (RF) seeker development for endoatmospheric and near-endoatmospheric missiles can provide a significant improvement in the capability to counter the Soviet tactical missile threats, and could be the basis for rapid, near term improvements to existing air defense systems to provide for increased capabilities.

Much of the SDI laser weapon developments would have application over the long term to conventional defense against tactical missiles, both cruise and ballistic.

Theater missile defense early warning and attack assessment functions will benefit from sensor technologies in that the defense will be able to identify the attack and implement appropriate active defenses and countermeasures on a real time basis.

The development of kinetic kill systems and associated guidance technology needed to accomplish space-based kinetic kill missions would provide a basis to improve ground-based systems used in anti-tactical missile roles.

CHAPTER THREE

POTENTIAL SDI CONTRIBUTIONS TO OTHER MILITARY MISSIONS

Other significant near-term military missions whose performance might be aided by the application of technologies developed under the SDI program include strategic and tactical air defense, maritime defense, access to space, and conventional missions such as anti-armor. This section of the report addresses the potential contribution of SDI technologies to these mission areas.

AIR DEFENSE

The air defense mission encompasses surveillance, warning, interception, and identification or negation of unknown aircraft which penetrate the air defense intercept zone. Systems which contribute to that mission in the continental U.S. include the Joint Surveillance System network of Air Force and FAA radars, the North American Warning System of radars across Alaska and Canada, Airborne Warning and Control Systems (AWACS) aircraft, and those fighter-interceptors on continuous alert. These systems will be augmented by the Over the Horizon Backscatter (OTH-B) radar network, which is scheduled to be operational in the early nineties. Although current systems are potentially capable of detecting, assessing and intercepting the anticipated threat, the technical promise of SDI could significantly improve air defense mission efficiency and effectiveness.

Tactical air defense in a theater of operations includes sensor systems such as the AWACS and mobile ground-based radar systems. These provide early warning and engagement control of Air Force air defense and Army anti-aircraft SAM systems such as PATRIOT and HAWK. This leads to a highly decentralized command and control environment, constrained by limitations in current battle management and communication, command and control systems.

Military Uses of Space: 1946-1991

Published by:

Chadwyck-Healey Inc., 1101 King Street, Alexandria, Virginia 22314

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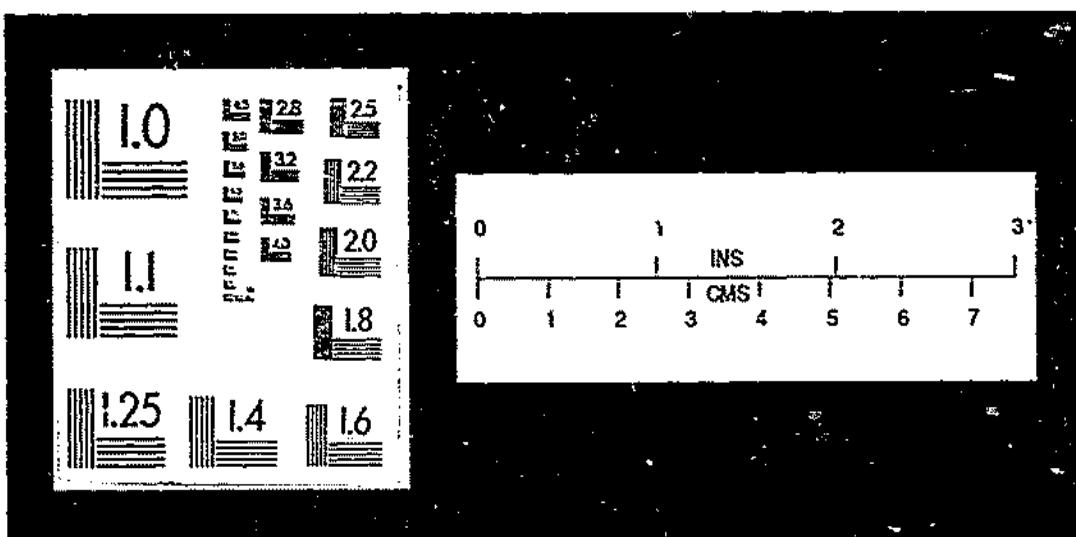
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NORAD assets operate as a system, with one type of surveillance asset compensating for the deficiencies of others. Improvements in sensor range, data processing and operating efficiency would greatly facilitate the NORAD mission.

Since aircraft can be diverted to many possible targets, it is difficult to discern the character of an airbreathing attack. However, broad patterns of mass raids can be revealed if information from multiple sensors can be assimilated simultaneously. Advances in survivable communications and distributed computation could significantly improve raid recognition, attack assessment, and the efficient assignment of interceptors.

Theater air defense operations are dependent upon limited sensor and BM/C³ architectures, which are in turn affected by electronic countermeasures and raid size. The addition of adjunct sensors using a variety of physical principles would ensure sustained operation and preclude a simplified development of countermeasures. Robust BM/C³ and data processing systems are needed to ensure that adequate theater air defense operations are maintained.

The NORAD surveillance mission could obtain substantial benefit from a variety of SDI efforts. Space-based sensors could detect aircraft activity and contribute information for attack assessment. SDI electrical power programs could provide long-term energy sources for unattended ground-based radar systems. Battle management and communications systems within the SDI program could facilitate sensor data fusion and attack assessment. At the global level, SDI computational technologies and simulation display advances could help integrate threat information necessary to respond to combined attacks. Sensor, kinetic energy weapons, and battle management technologies pursued by the SDI would all be applicable to the strategic air defense mission.

Theater air defense operations would also benefit from the development of SDI technologies. For example, as discussed above, the extension of air defense systems to a more robust anti-tactical and anti-cruise missile role could be derived from SDI experiments; early warning attack assessment functions would benefit from sensor development; missile lethality enhancements could be based on improved lethality/vulnerability analyses; and command, control and data processing shortcomings

could be improved as a result of the software development and signal data processing work being accomplished for SDI.

As currently envisioned, many of the SDI technologies discussed above could be phased into air defense systems within a decade. Their integration into air defenses will require continual monitoring of SDI research advances in order to apply technologies appropriately. The Air Defense Initiative (ADI) is examining, *inter alia*, the contributions of SDI technologies to improved air defense.

ACCESS TO SPACE

The scope and nature of future U.S. operations in space in support of national security as well as civil and commercial activities will be largely determined by the availability of high capacity, low cost space transportation systems. The recent spate of space launch failures, and the critical examination of the U.S. space launch posture which resulted, have made it clear that the current family of U.S. launch vehicles lacks the robustness, reliability and cost effectiveness needed to support the anticipated expansion of U.S. operations in space.

Since the completion of the Space Shuttle's R&D program in the early 1970s, there has been no significant U.S. investment in the technology base needed to support development of advanced space transportation systems. Current systems provide access to low earth orbits at a cost between three and five thousand dollars a pound. Because many components of space-based defenses would be unaffordable at these cost levels, the SDIO has a vested interest in supporting development of the technology base and systems needed to support a deployment of the space-based elements of any future ballistic missile defense system. In doing so, however, SDIO will contribute to the solution of a larger national problem--how to achieve a cost effective and reliable launch posture that will carry the nation into a greatly expanded role in outer space in the twenty-first century.

Technologies developed by SDI would assist the nation in developing the capability to move beyond our present limited capability to launch relatively small payloads to one

permitting the lifting into space of larger and heavier payloads. Insofar as SDI would involve the ability to develop the capability to launch such payloads, the United States would obtain the ability to deliver payloads of varying size at a high rate. We would expect to drive launch costs down dramatically, thus achieving the benefits of economies of scale. Other advantages to the nation would include the development of rapid lower-cost launch capabilities to support national weather monitoring, surveillance, communication and navigation systems.

Increased launch capacities would also provide the ability to develop maintenance systems to be deployed for on-station repair or service of deployed satellites, thus extending their useful life and reducing costs. Maintenance procedures developed for logistics support of space-based assets would also provide new technologies that would improve the maintenance of national satellite systems.

A major expansion of SDIO's funding for technology base activities in support of advanced space transportation systems is planned. Based on the results of the ongoing Space Transportation and Architecture Study (STAS), both concept definition and technology base programs would be expanded. The NASA/DoD STAS studies have indicated that an unmanned Advanced Launch System (ALS) will be needed to satisfy national space launch requirements. Although a specific system concept has not been selected, it is generally believed that this system will be some form of a two-stage, vertically-launched, partially reusable rocket vehicle. DoD technology investments in space transportation are closely coordinated with NASA to ensure they are complementary.

To augment these technology thrusts, system concept definition efforts will be initiated to begin definition of a family of Advanced Launch Systems (ALS). These concept definition efforts will aid in the definition of refined technology programs, and lay the groundwork for system development efforts should they be approved.

MARITIME OPERATIONS

The global maritime operations of U.S. naval units and fleets in both peace and war are critically dependent on surveillance, communications and the ability to intercept hostile forces beyond the range at which they can actively threaten fleet units. The U.S. Navy is confronted by a Soviet maritime threat of growing size and sophistication, a multi-dimensional force that possesses demonstrated capability for surveillance, track and attack from space, air, surface and subsurface platforms. Existing Navy defenses involve multiple layers and redundant systems, much in the manner proposed for a layered strategic defense against ballistic missiles.

Massive raids of Soviet land-based bombers with each bomber carrying numbers of sophisticated anti-ship missiles (ASMs), present an especially serious threat to the surface fleet. The bombers must be intercepted before they launch their ASMs from standoff ranges. In the near term, the SDI first generation surveillance satellite could significantly extend the range for detection of bombers, and would augment naval airborne early warning radars to support timely launch of sea-based fighters and long range shipboard anti-aircraft missiles. Technology spinoffs from the High Endoatmospheric Intercept (HEDI) program could contribute to the development of a long range ship-based missile for intercepting bombers before they reach ASM launch range and for suppression of Soviet standoff jammer aircraft.

Spinoffs from advances in communications, multiprocessors, intelligence interfacing and software now under development by SDI to meet the demanding battle management and C³ needs of a global strategic defense system, should greatly benefit fleet operations in both the near and far term. For example, the battle management software developed to track and intercept thousands of ballistic missiles and RVs should be readily adaptable to the Navy's less stressing requirements to perform similar operations involving lesser numbers of seaborne and airborne friendly and hostile objects. Further, SDI software development tools employing artificial intelligence and knowledge-based technology should markedly reduce the cost and time required to develop and manufacture secure and fault-free software for tactical use.

In the longer term, it is expected that the Soviet bomber ASM launch range and countermeasure capability will increase. The SDI optical sensor technology employed in the second generation surveillance satellite, if applied in naval aircraft and air-defense missiles, could help fleet defenses keep pace with advances in the bomber threat. The SDI space-based radar would provide a valuable multispectral surveillance mix with optical sensor satellites. Spinoffs from the SDI hypervelocity gun and laser technology could result in highly effective ship-based weapons for defense against an anticipated new generation of Soviet anti-ship cruise missiles. For example, a rapid-fire electromagnetic gun ("railgun") that propels a low-cost guided projectile at a velocity of 5 to 10 km/sec at long range would be very attractive for defending against Soviet ASMs launched from bombers, ships or submarines. Applications of SDI laser weapon technology (Excimer, free-electron, and chemical) could provide the quick kill defensive capability needed to counter even the most advanced Soviet ASMs. Advances made in developing high power microwave technologies for SDI purposes has potential application as seaborne tactical weapons.

CONVENTIONAL FORCES

For conventional ground force operations in a European general war, the Soviets have deployed a vast array of weapons to provide massive firepower. This array includes tanks, mobile artillery and armored personnel carriers as well as sophisticated attack helicopters. These weapons are designed to provide the mobility and firepower necessary to overwhelm NATO forces without resort to nuclear weapons.

As a counter to this Soviet/Warsaw Pact capability, conventional NATO forces require an infusion of new technologies to provide improved capabilities in the areas of fire power, fire control, command, control and communications and improved power supplies to enhance the mobile operations of advanced weapons.

The SDIO is developing a range of advanced technologies which could be used in developing advanced weapons and support or control systems for conventional forces. These include, for example:

- Lightweight, rapid-fire hypervelocity gun technologies could provide significant improvements in anti-armor, anti-aircraft, and fleet defense operations. These kinds of systems could be capable of rapid, lethal response to conventional attack, especially when coupled with low cost guided hypervelocity projectiles. These technologies may provide the synergy needed to develop an effective long range deterrent to conventional threat systems.
- The development of power supplies with high power density could provide a significant benefit to the modern conventional force, especially command and control and support elements. The technical improvements being made in communications, battle management, and resource allocation are also generating greater demands on the design of effective power supply systems that can provide sufficient power with low noise and/or thermal signatures. Lightweight, quiet power systems would contribute to the reduced signature of critical units and thus enhance survivability while meeting power needs.
- The ability to engage more than one target at a time is being developed through advances in computer aided or controlled multi-target fire control systems. This would enhance the battle management functions of all forces and enhance their efficiency in the use of resources.

Recent experiments have demonstrated technologies related to hyper-velocity weapons development and have demonstrated these capabilities:

- Rapid fire operations of greater than 10 shots per second; launch efficiencies of greater than 50 percent; projectile mass fired of up to 700 grams; and electronic switch operation of up to 500 kiloamperes.

Within several months, launch energies will probably be increased to levels approaching artillery shell muzzle energies.

The SDI program is pursuing technology for advanced fire control systems to track multiple targets and guide hypervelocity projectiles to targets. Included are lightweight command guided projectiles with cost goals of \$20,000 per round. The launch velocity goal is 5 kilometers/second. Such projectiles could provide an air defense or anti-armor capability.

In another critical area, the SDI program is developing technologies to automate the collection, fusion and processing of massive amounts of intelligence data on a near real-time basis. The application of expert systems will further facilitate processing the data to allow force structures to be categorized and tracked. These developments can ensure the timeliness and availability of reliable intelligence to keep pace with increased application of heliborne and mobile forces on a battlefield.

CHAPTER FOUR

SPACE DEFENSE

SUMMARY

The defense of U.S. military space assets is increasingly important as the Soviets maintain their present co-orbital interceptor, develop large-scale directed energy facilities with satellite attacking and potential ASAT capability, and maintain a potential direct ascent interceptor capability with their deployed ABM interceptor, the nuclear-tipped GALOSH. The SDIO is fully committed to researching systems that will remain effective in the face of these dedicated efforts to defeat them. We are funding major investments in the technologies needed to enhance the survivability of space- and ground-based elements of any future ballistic missile defense system.

This section summarizes SDI contributions to provide sufficient warning and tracking information to support satellite survivability as well as a means to defend, evade, or counter attack against U.S. military satellites. Particularly relevant are SDI technologies being developed for eventual Space Surveillance and Tracking Systems (SSTS), Space-based Kinetic Kill Vehicle (SBKKV), Exoatmospheric Reentry Vehicle Interceptor (ERIS), and Ground Based Laser (GBL) systems, as well as capabilities for responsive or random maneuver and nuclear, fragment and laser hardening of space platforms.

PROGRAM STATUS AND KEY TECHNOLOGIES

The problem of space defense comprises three areas which are discussed in turn:

1. Space Surveillance and Tracking;
2. Space Defense Weapons; and
3. Passive and Active Countermeasures.

Currently, the SPADATS sensor network operated by NORAD/USSPACECOM gives the U.S. the ability to locate and maintain track files on satellites. This network includes radars and visible/infrared systems. Space Object Identification uses radars and optical means for low orbit satellites. The SDI program offers a wide range of sensor, radar and laser technologies that have potential application for improvements in this area.

The current threat posed to U.S. low orbit satellites by the operational Soviet co-orbital fragmentation interceptor is of immediate concern. Maneuver is one possible countermeasure. A Soviet direct ascent nuclear ASAT targeted against a low orbit U.S. satellite requires development of a self-defense capability.

In the long term, interceptors or other means of "shoot back" are likely to be required. Ground-launched or other interceptors could be used. For example, a space-based interceptor positioned near the defended platform would draw on the technology in the current SBKKV interceptor program. Laser weapons currently under consideration potentially represent a longer term alternative with lower marginal cost per shot.

A third category of space defense technologies involves passive and active countermeasures. The U.S. has worked over the last decade on hardening satellite systems. Because we must anticipate operations in a future wartime environment with advanced technology defense suppression threats, the SDI program has invested in survivability technology aimed at protection far above current levels. Passive countermeasures research includes ablative and radiation shielding, mass shielding and hardened chip technology. Active countermeasures will also be considered.

FUTURE PLANS

SDI is proceeding with the technology elements discussed in coordination with other DoD elements. Major demonstrations are planned to show engineering feasibility for selected items such as the SBKKV and ERIS interceptors, the TIR radar and selected countermeasures techniques. The costs for most of the items discussed have not been developed in detail. A few exceptions exist, such as ERIS, where definite cost goals of \$1 million or less per interceptor for deployed quantities have been established based on current understanding of both technology and requirements.

CHAPTER FIVE

EARLY WARNING AND ATTACK ASSESSMENT

SUMMARY

Early Warning and Attack Assessment (EW/AA) provides crucial information required by decision-makers to allow them to respond to a ballistic missile attack. This function is essential for a deterrent policy based on offensive retaliation, defensive capability or a combination of both. EW/AA for strategic defenses will be accomplished using the complete suite of SDI sensors tied into the Battlefield Management and Command, Control and Communications (BMC³) systems. These sensors would complement existing and planned systems. For a multi-tiered SDI system, early warning and initial attack assessment will occur in the boost phase. However, later tiers—post boost, midcourse and terminal—will provide additional sensor information on ballistic missiles or their deployed reentry vehicles (RVs). This SDI surveillance and tracking capability will also enhance our current offensive-based deterrent posture. EW/AA functions are important in all aspects of defensive operations. The sensors being developed in support of SDI goals could provide similar support to conventional defense elements, aid in the proper assessment of information, and help develop appropriate warning.

EW/AA functions related to missile defense are described as follows:

Boost Phase. Initial EW/AA will be provided during the boost phase by the Boost Surveillance and Tracking System (BSTS). This new satellite system will provide significantly more survivability and better performance than current system capabilities. BSTS will detect the launch of ballistic missiles and will provide rapid alert to the National Command Authority.

Post Boost Phase. The post boost phase occurs as the Post Boost Vehicle (PBV) leaves the atmosphere and begins deploying its RVs and decoys. The BSTS tracks this deployment. During this phase, as the RVs fly a ballistic trajectory, more accurate information about the enemy's targets and intent could be provided for a strategic defense

system. The battle management would use this information to prepare subsequent tiers for their defensive roles. This information can also aid in the timely management of offensive strategic forces.

Tracking using the SDI Space Surveillance and Tracking System (SSTS) would begin during this phase. This system would track the RVs and other objects using advanced sensors. Using stereo processing in conjunction with other SSTS satellites, this system would be able to track objects with improved accuracy compared to single satellite performance. Information for attack assessment would then be more accurate and would begin to include the number of Reentry Vehicles as well as their target locations.

Midcourse Phase. Objects deployed from the Post Boost Vehicle travel ballistically through space. SSTS satellites, which began tracking in the Post Boost Phase, would provide increasingly accurate attack assessment to subsequent tiers as threat objects progress along their trajectory. During the later part of the midcourse phase, other systems including the Long Wavelength Infrared (LWIR) Probe and the Airborne Optical System (AOS) would start to track the threat cloud. The LWIR probe would provide back-up for the SSTS system utilizing stereo processing. The AOS would track threat objects during late midcourse and as they reenter the atmosphere.

Terminal Phase. As the objects reenter the atmosphere, the AOS could also provide greater accuracy and final attack assessment. It would alert and cue the terminal radars, which would provide final attack assessment of the surviving Reentry Vehicles that must be destroyed by Endoatmospheric interceptors.

Survivable Command, Control and Communications (C3). In order for each tier's suite of sensors to provide continuous early warning and attack assessment, survivable C3 systems must be built. Systems contemplated by SDI complement C3 systems already in place and being upgraded by the Air Force. SDI would build upon these existing systems in order to provide continuous C³ functioning via highly survivable communications links. Command and control nodes will be proliferated on various weapons and sensors platforms, thereby reducing the vulnerability of the complete system. In order to provide highly survivable communication links, directional links would be

used. Because of their directional nature, these links would be highly resistant to jamming. Both ground- and space-based nodes would be linked through existing and improved command, control and communication facilities. SDI will provide the technology to implement most of these improvements into existing C³ systems even if the decision is made not to deploy strategic defenses.

PROGRAM STATUS

Experiments which will support development of SDI early warning and attack assessment concepts are listed in this section along with supporting technologies. These experiments include the Boost Surveillance and Tracking System (BSTS) Experiment, Space Surveillance and Tracking System (SSTS) Experiment, Airborne Optical Adjunct (AOA) Experiment, Long Wavelength Infrared (LWIR) Probe Experiment and the Terminal Imaging Radar Experiment.

BSTS Experiment. The BSTS will complete System Design Review (SDR) in FY 87, verifying the BSTS system requirements. The Preliminary Design Review (PDR) to verify the design of the system is scheduled for mid FY 88. The Critical Design Review (CDR) will be conducted in FY 90 and will freeze the design of BSTS and provide final approval for the experiment. Technology efforts supporting a BSTS experiment and a future system include:

- Dynamic Isotope Power System (DIPS) scheduled for availability in 1990.
- Infrared Focal Planes with Mercury Cadmium Telluride detectors, with modules to be built in FY 88 and pilot line production scheduled for FY 90.
- Hardened Beryllium mirrors to be demonstrated in FY 87 and production capability planned for FY 89.
- Radiation-hardened Very High Speed Integrated Circuit (VHSIC) technology to be demonstrated in FY 88, and a VHSIC computer to be developed by FY 90.

These technologies will provide real time processing of information in a nuclear environment. This capability significantly reduces the amount of data to be transmitted and therefore enhances survivability.

Several measurements programs support the BSTS: The Third Color Experiment scheduled in FY 88, Infrared Background Signature Survey scheduled in FY 89, and the nuclear effects experiment, EXCEDE, scheduled in FY 90.

SSTS Experiment. The SSTS experiment is scheduled for System Design Review (SDR) in late FY 87. A Preliminary Design Review (PDR) is scheduled for late FY 88 and Critical Design Review (CDR) in FY 90. Several technologies support the SSTS:

- Long Wavelength Infrared (LWIR) focal planes are being developed under several different technology programs. These programs are stressing radiation-hardened Impurity Band Conductor (IBC) devices which will allow detection of RVs against a cold space background. Modules for the focal planes will be developed by FY 88 and experimental production lines established in FY 90.
- Cryocoolers to cool the LWIR focal planes to tens of degrees Kelvin and operate for years are being developed. Accelerated tests of these systems are now being conducted, with prototypes to be developed in FY 89.
- Hardened mirrors developed for BSTS will also support development of the SSTS as will onboard signal processing.
- Several measurement experiments will provide additional information on targets and background: Delta 181 flights, CIRRIS, SPIRIT, and EXCEDE.

Airborne Optical Adjunct (AOA) Experiment and LWIR Probe Experiment. The AOA experiment has completed its Critical Design Review. The LWIR

Probe is scheduled for PDR in FY 88 and CDR in FY 90. Technologies supporting these devices are essentially the same as those that support the SSTS experiment.

Terminal Imaging Radar (TIR). The TIR has completed System Design Review (SDR) in 1986, and is scheduled for a PDR in FY 90. The CDR is scheduled for FY 88. Several technologies support the TIR, including the development of solid state transmit/receive modules.

Discrimination. Discrimination technologies will provide resolution of closely spaced objects and accurate differentiation between actual RVs and replicas. These programs are researching the use of imaging lasers and radars as well as different interactive discrimination techniques. Discrimination programs are scheduled to provide additional capabilities as the Soviets develop better decoys and more closely spaced objects.

FUTURE PROGRAMS AND COSTS

BSTS. A system based on the BSTS experiment is scheduled to begin Full Scale Engineering Development (FSED) in FY 89. Cost of the deployed system is yet to be determined.

SSTS. Experimental costs are estimated at \$2.2 Billion. The Initial Operational Capability (IOC) and cost of the deployed system will depend on the number of satellites and their complexity.

AOA and LWIR Probe. The AOA experiment will provide the basis for an airborne surveillance system. The cost of the AOA experiment is estimated at \$550 million. Systems costs are yet to be determined.

TIR. The TIR experiment will provide the basis for an SDI ground-based radar. TIR experimental costs are estimated to be \$325 million.

In summary, the EW/AA program is providing valuable potential for an effective network of surveillance assets that would serve the United States in a variety of strategic, tactical and conventional roles.